



The first hour in the life of a Gamma-Ray Burst

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&

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Outline

- Introduction
- Example results from Swift
- Joining BAT (γ -ray) & XRT (X-ray) data
- GRB X-ray light curves – the movie
- Constructing a mean spectrum
- What about short bursts?
- Conclusions

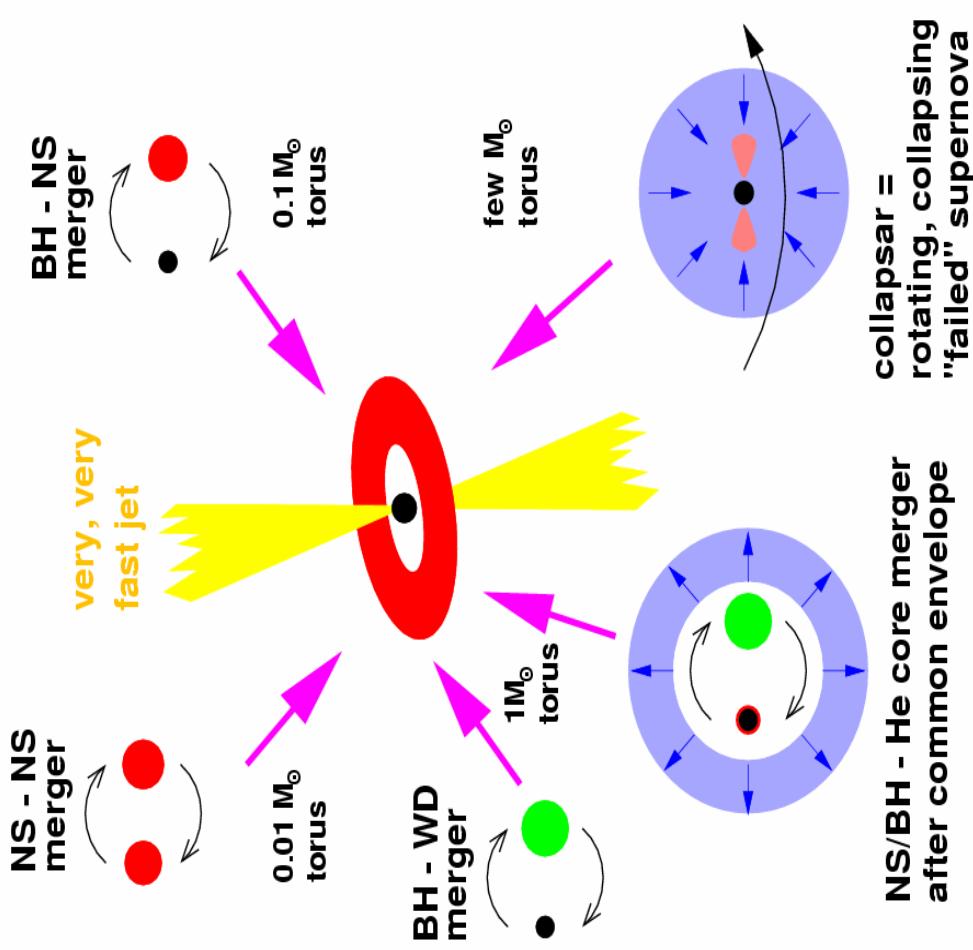




GRB models



Hyperaccreting Black Holes



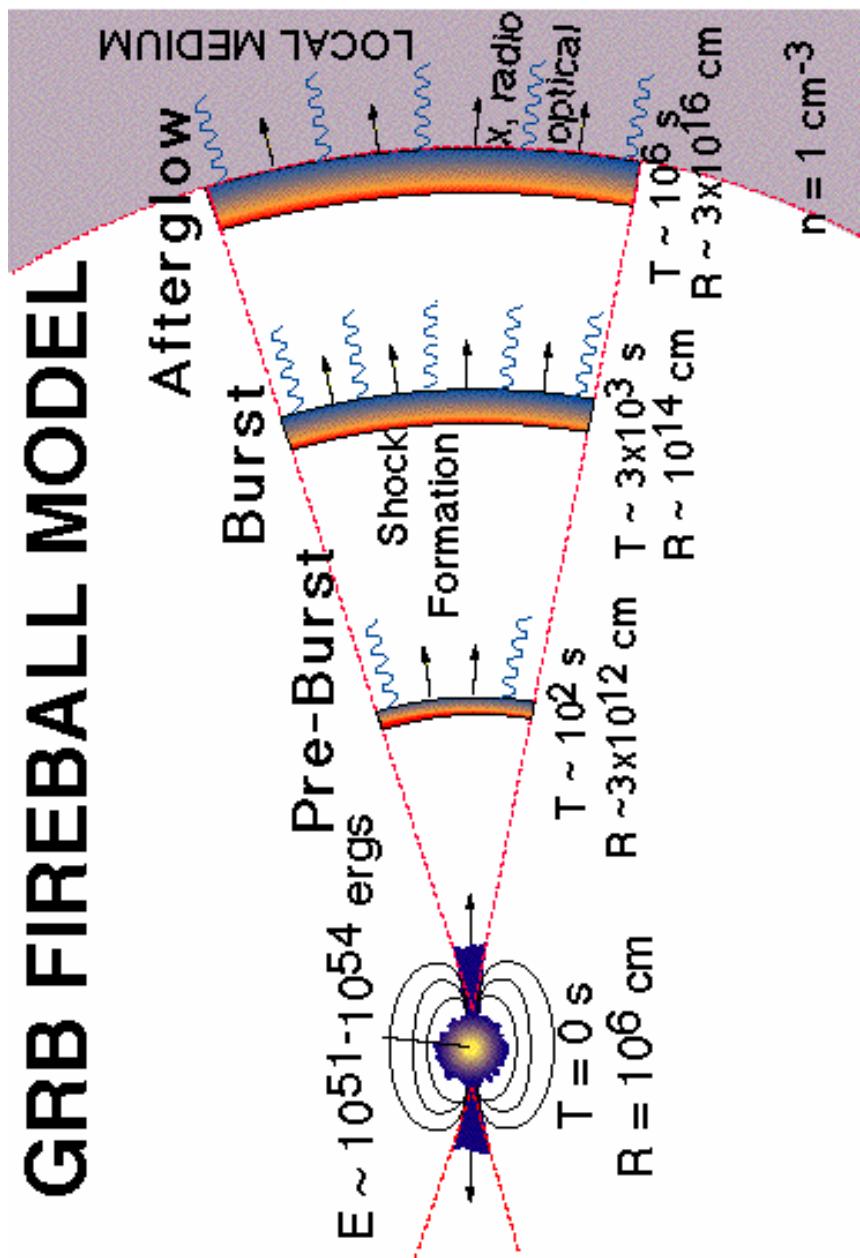
M. Ruffert, H.-Th. Janka, 1998



GRB emission mechanism

The emission is probably due to shocks (internal and external) in an ultra-relativistic expanding fireball as it interacts with the surroundings. What dominates early on?

GRB FIREBALL MODEL





Pre-Swift : data gap



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luminosity

Prompt Gamma-ray Emission by Internal Shocks

External Shock emission(?)
Typical freq. : X-ray-> optical -> radio

GAP in observations

(pre-Swift Era)

~10 sec

a few hrs

time

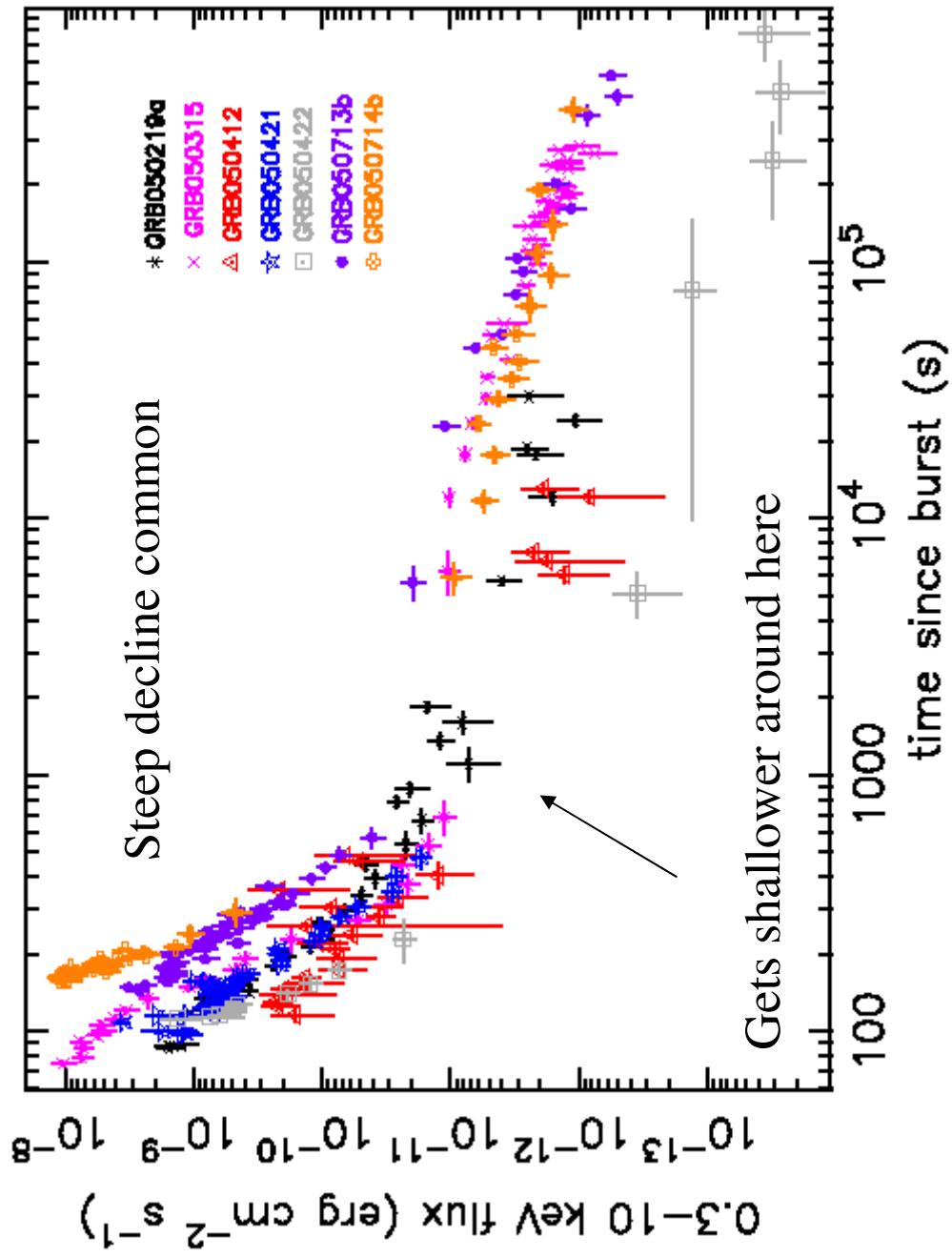
a month



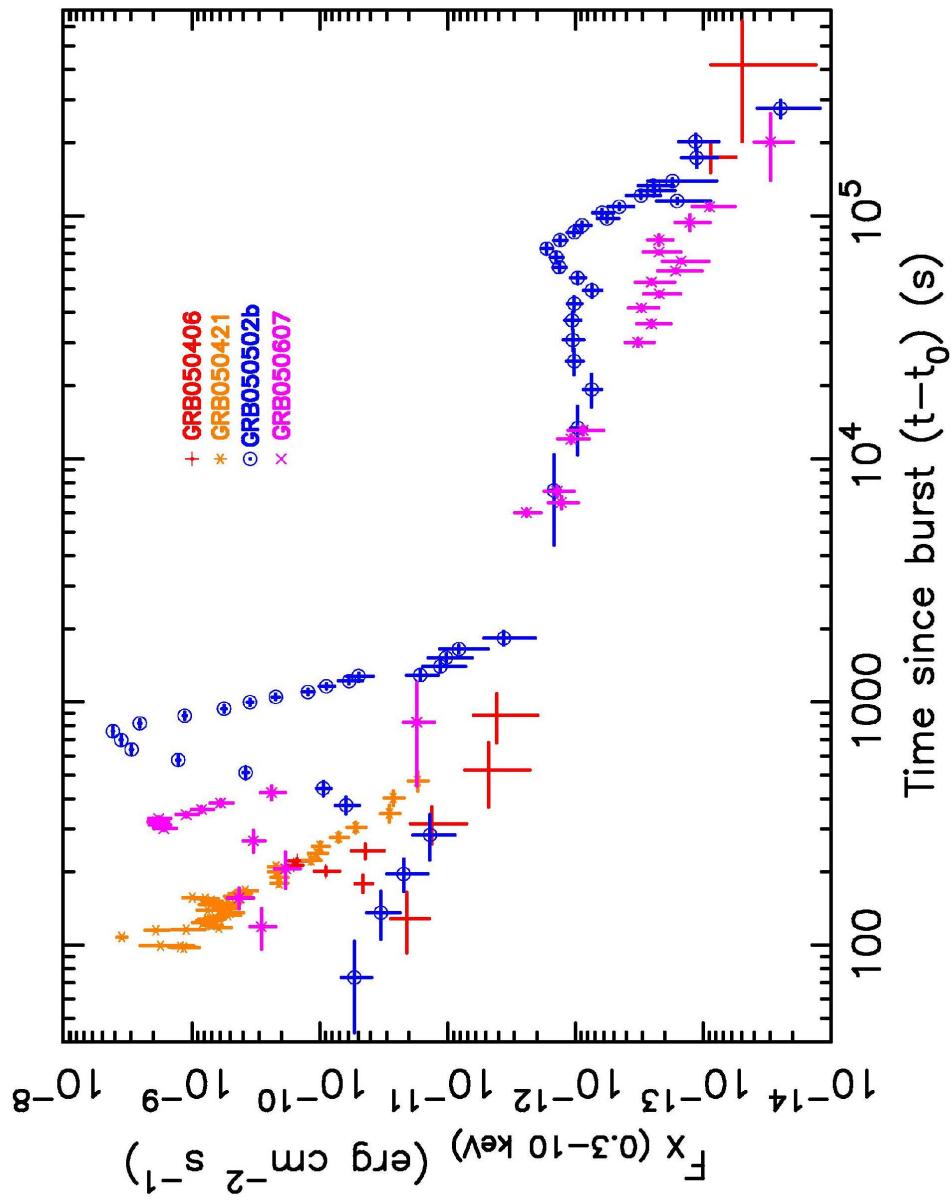
Example XRT Light Curves (e.g. Nousek et al. 2005, ApJ, submitted)



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Flares, wiggles and bumps

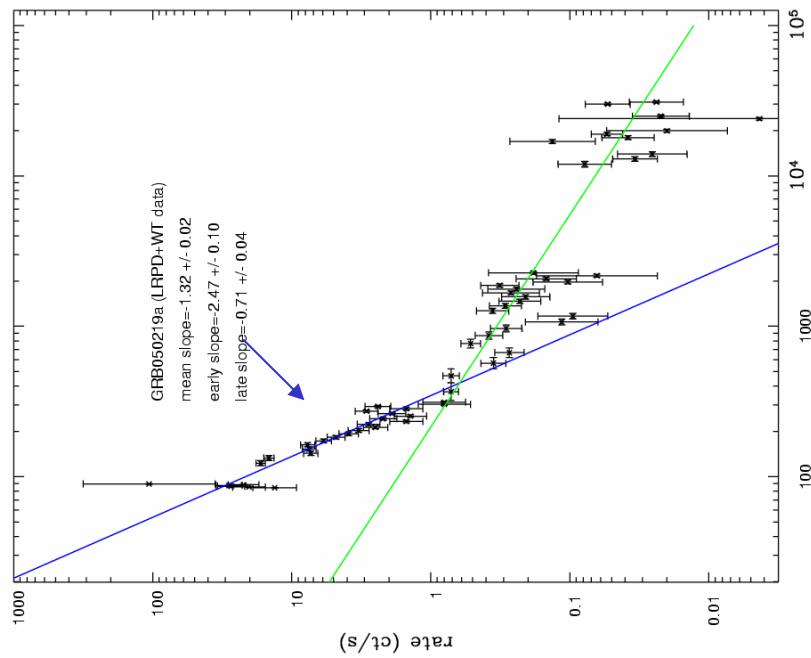
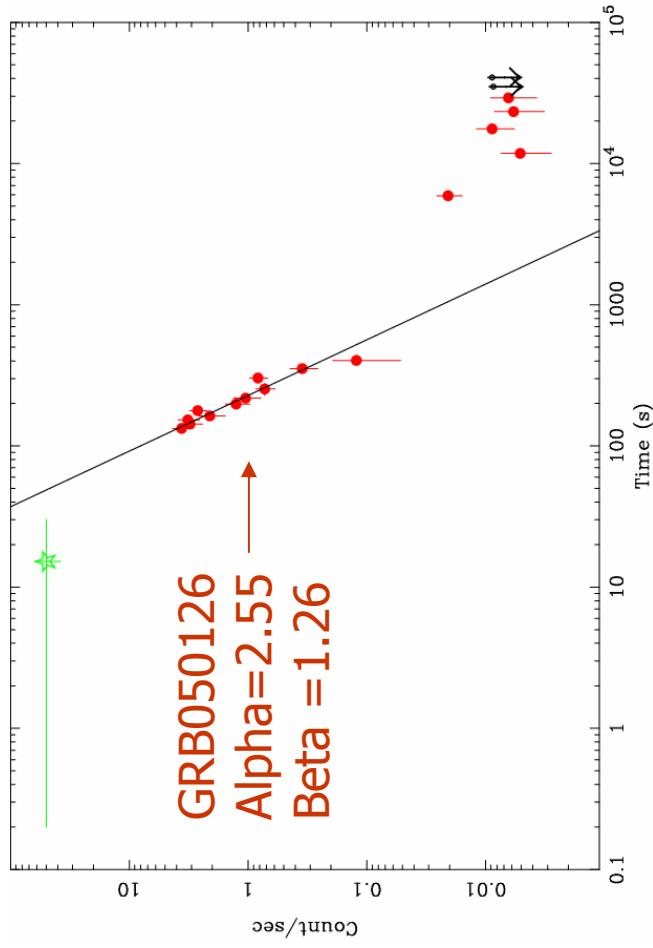




Early simple fits

- Initial Steep decay
- Breaks at several hundred sec
- Need to adopt a zero time (= trigger time)

$$F_\nu \propto t^{-\alpha} V^{-\beta}$$





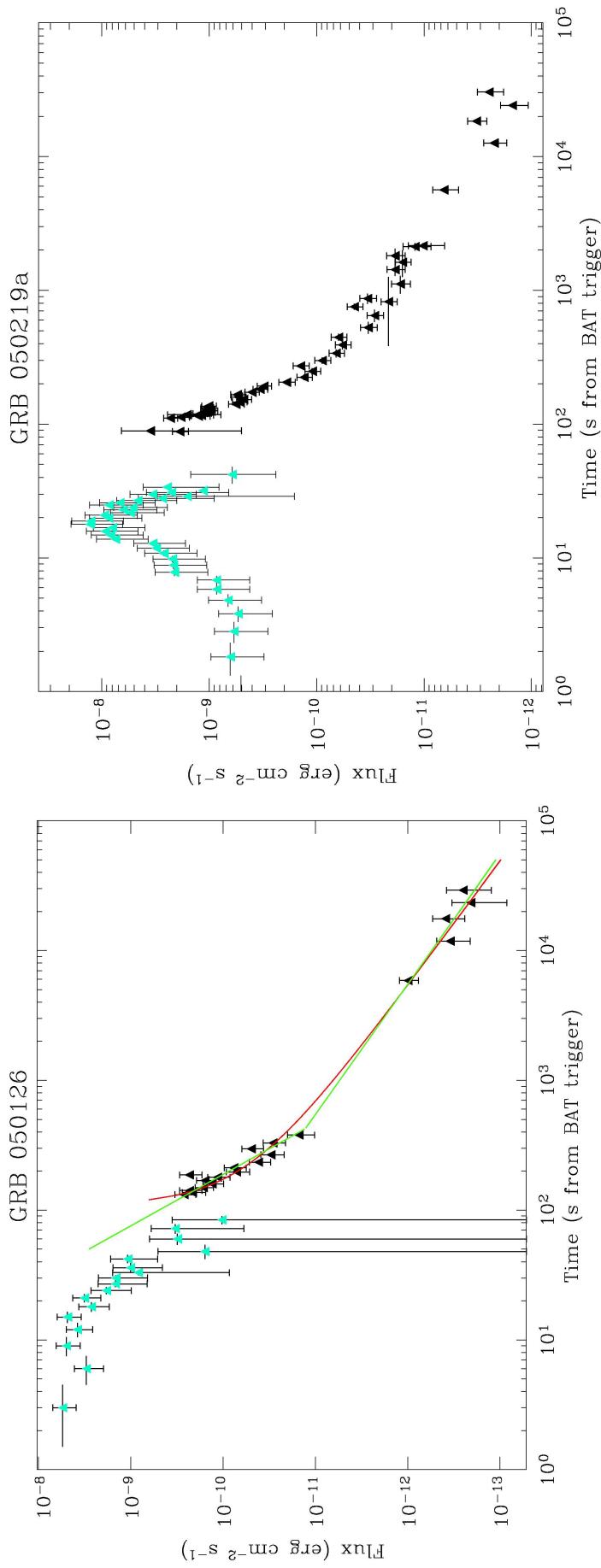
Early BAT+XRT examples



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BAT & XRT “join up”

BAT & XRT don’t “join up” (?)



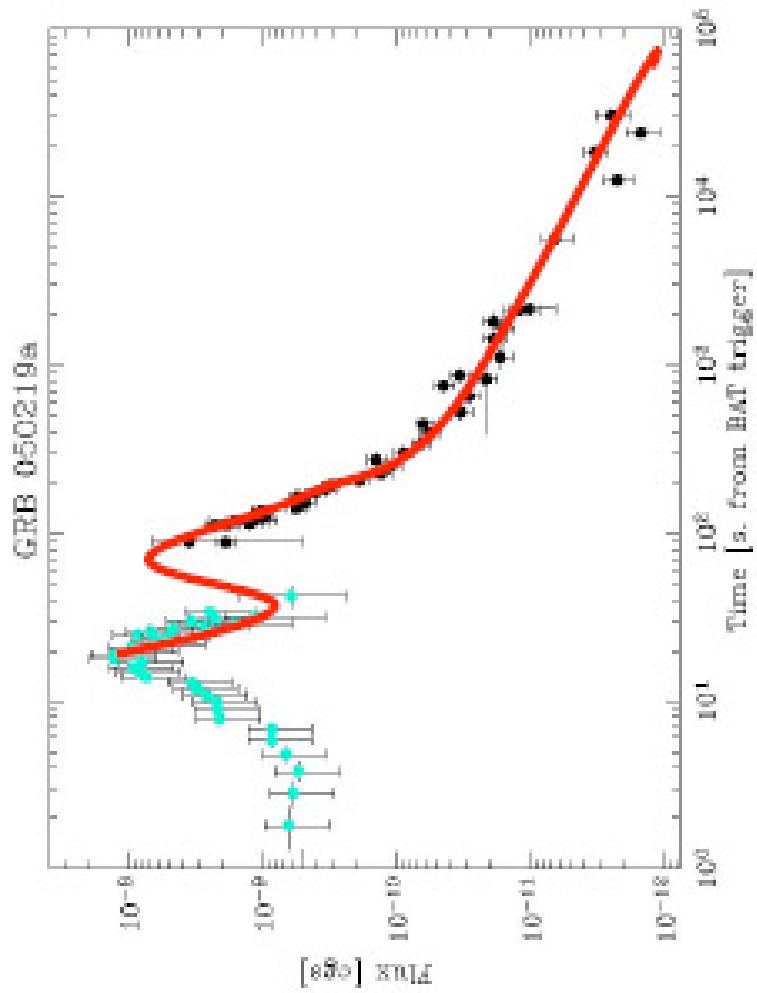
Tagliaferri et al. (2005, Nature, 436, 985);
Goad et al. (2005, ApJ, submitted)



GRB050219a with flare ?



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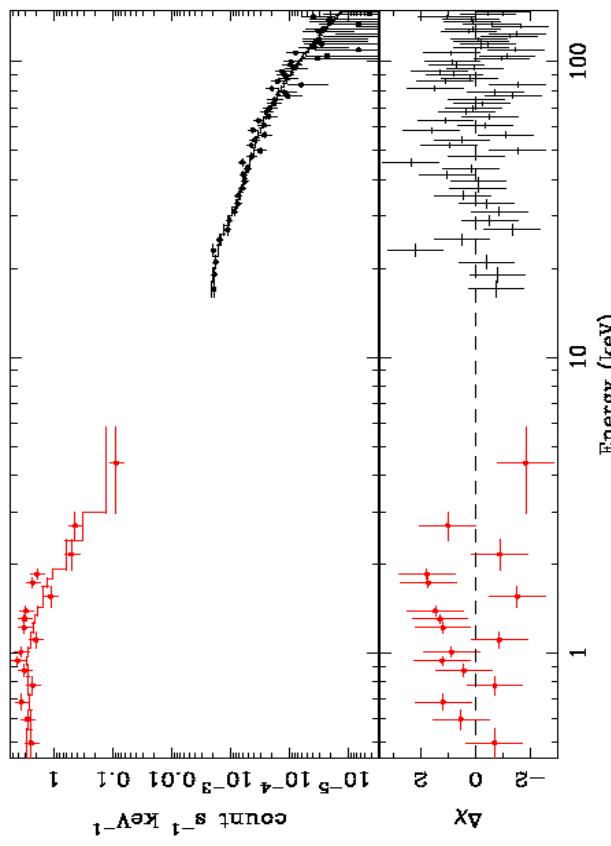


GRB 050315

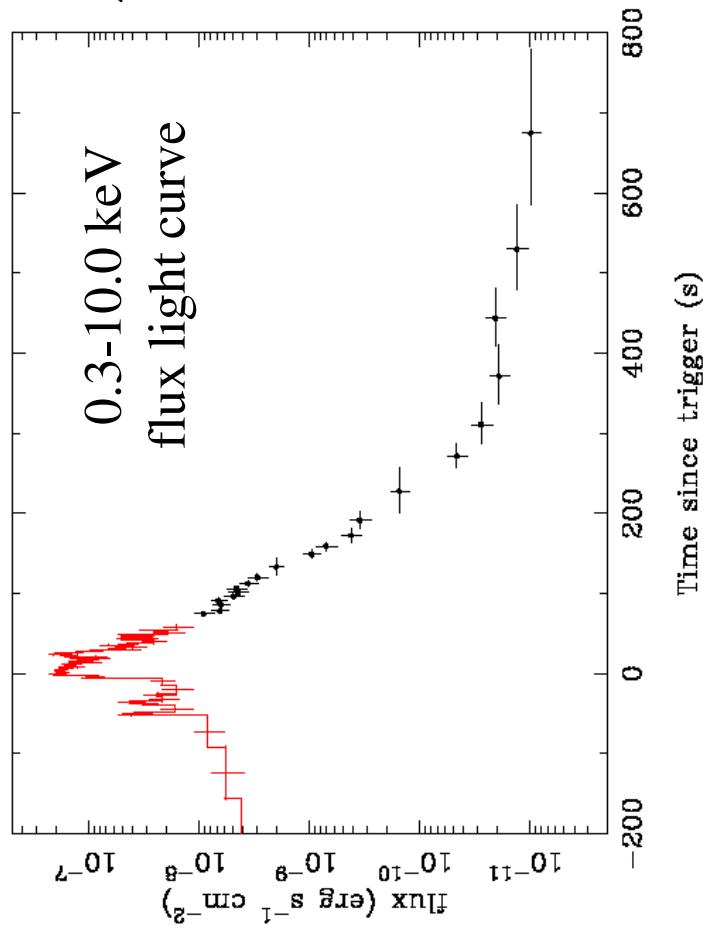
(Vaughan et al. 2005, ApJ, submitted)



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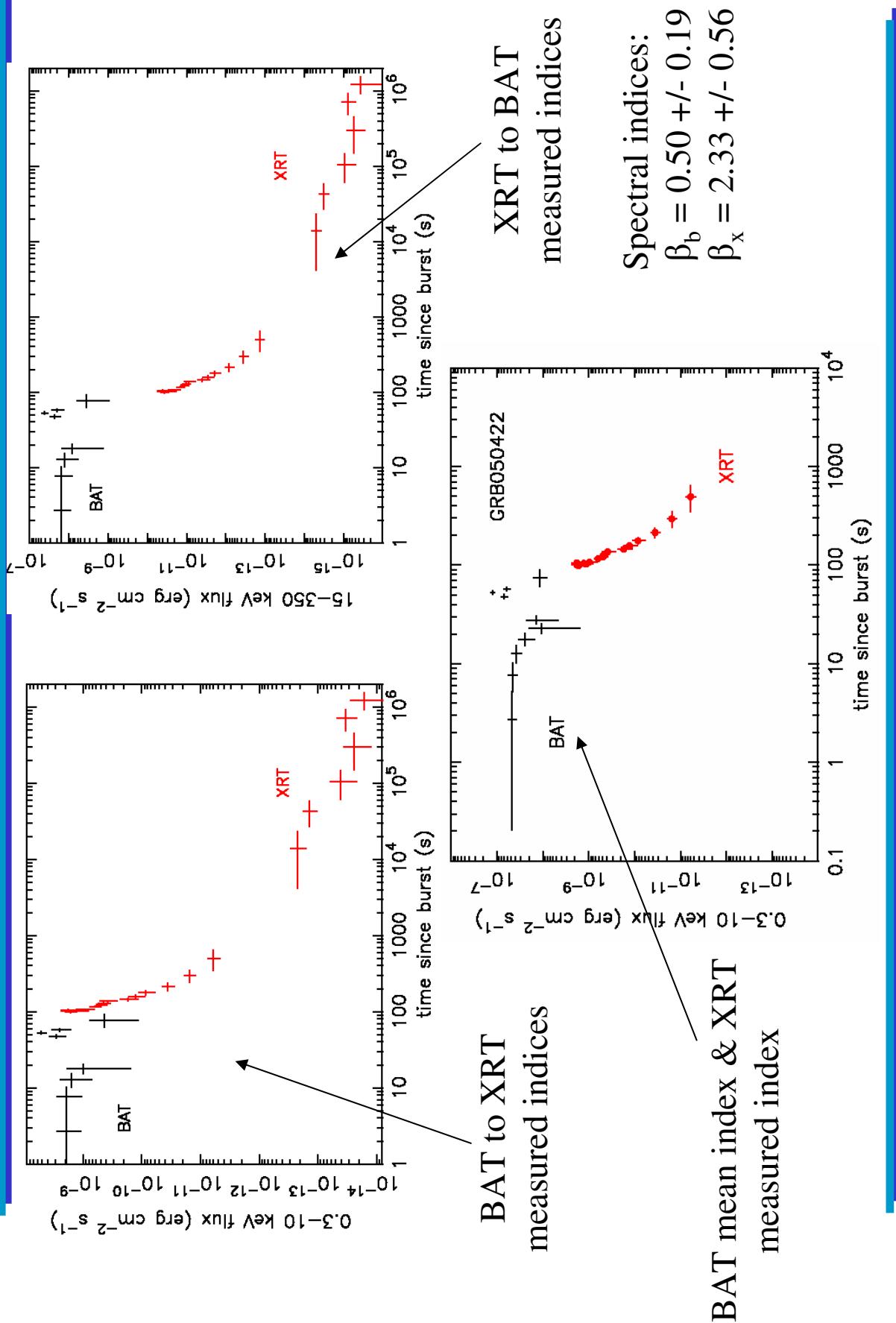
BAT/XRT spectral slopes are similar
BAT $\beta_b = 1.15$
XRT $\beta_x = 1.50$



The BAT & early XRT emission
are clearly related in this GRB.



GRB050422-BAT/XRT light curves





GRB sample (up to 25/8/05)



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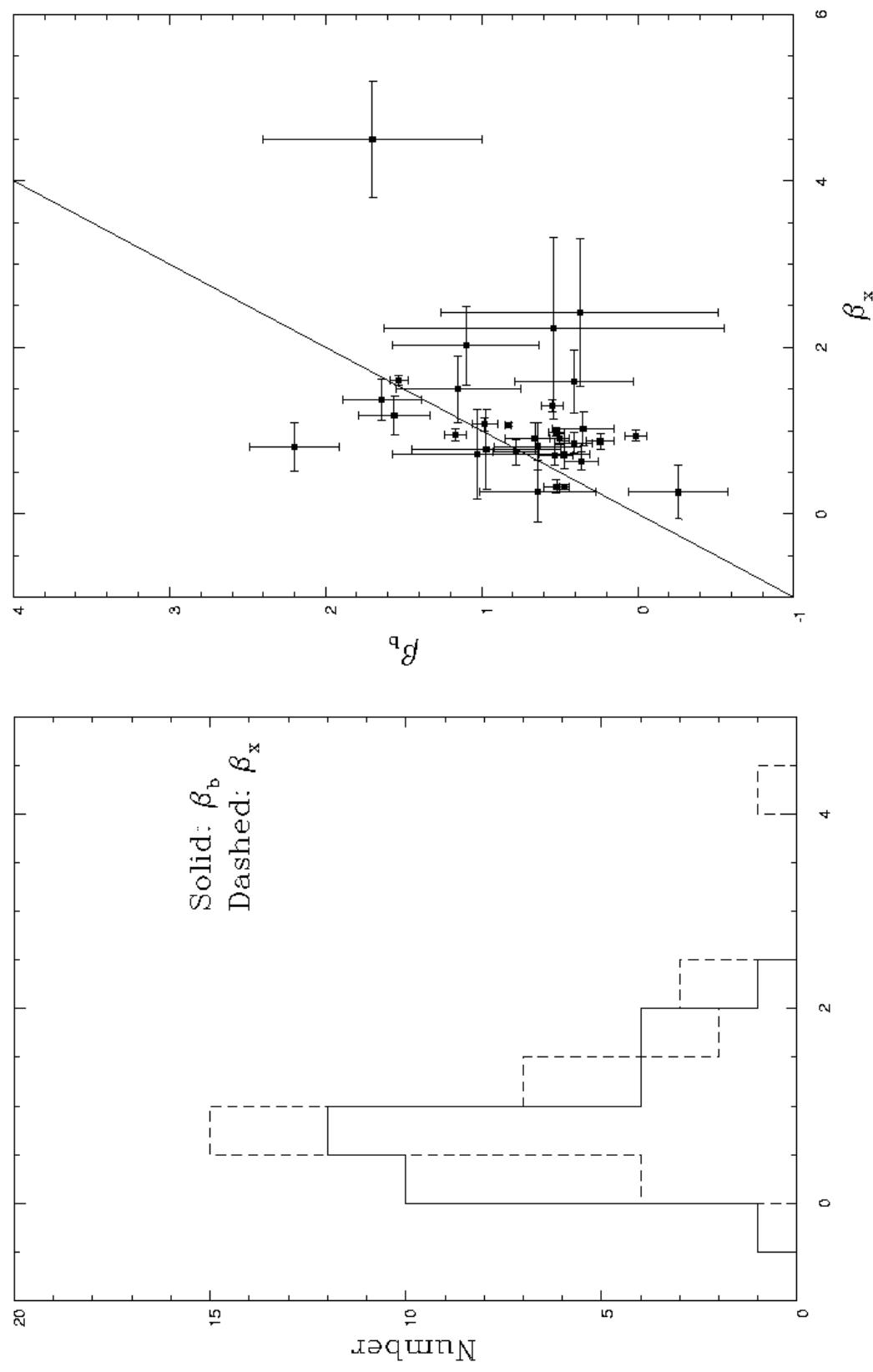
- Take all (32) GRBs with significant data in first 5 minutes
- Extract BAT and XRT data and use simplest possible spectral fit (absorbed power law ($\propto v^{-\beta}$) or cut-off power law)
- Fit to XRT light curves using functions $\propto (t - t_s)^{-\alpha}$
- Take t_s to be the BAT trigger time
- Convert XRT counts to 0.3-10 keV flux using early β_x
- Convert BAT counts to 0.3-10 keV flux by extrapolating using the mean XRT+BAT spectral index as we tend to see $\beta_x > \beta_b$



BAT vs. XRT spectra



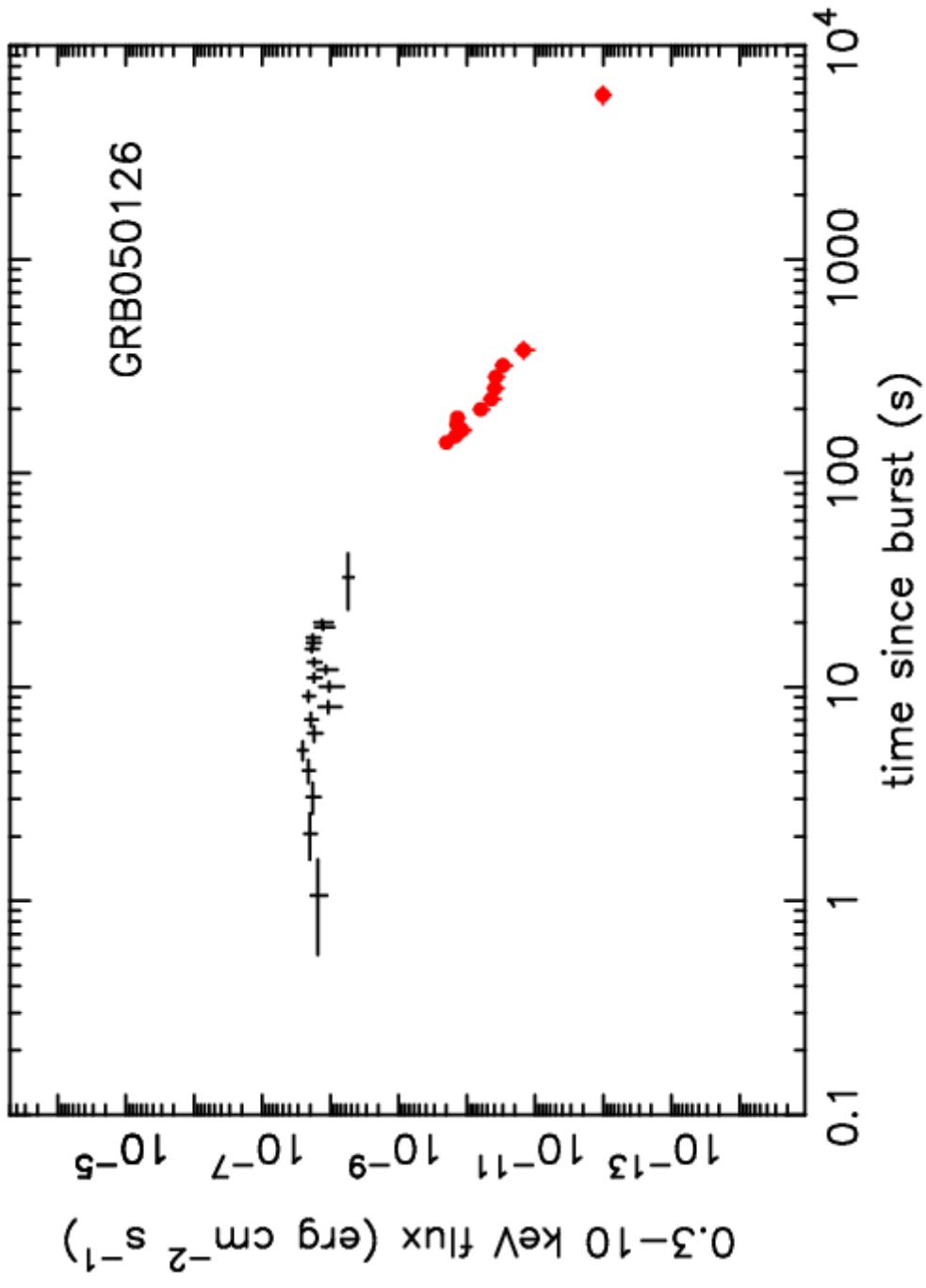
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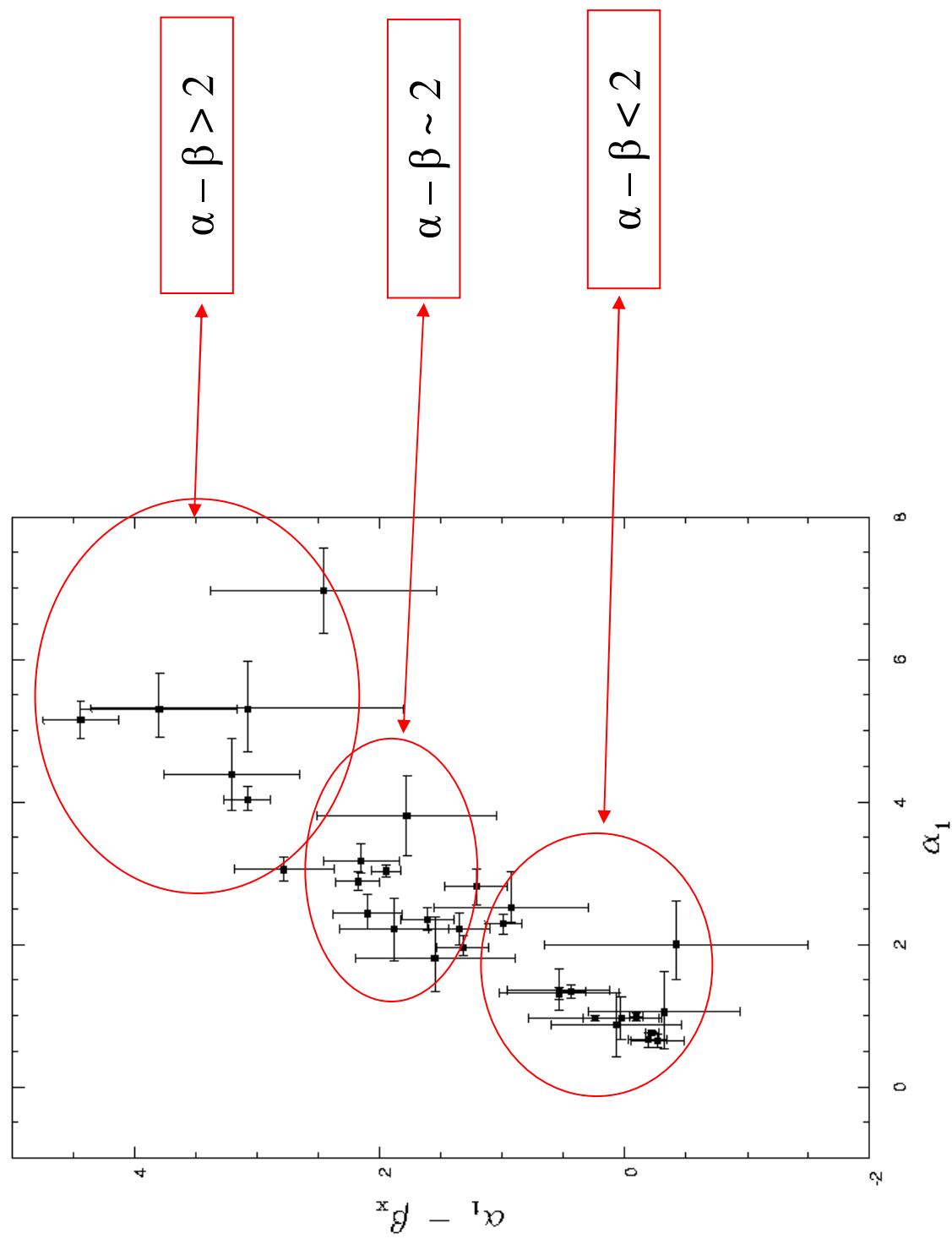
Swift light curves – the movie

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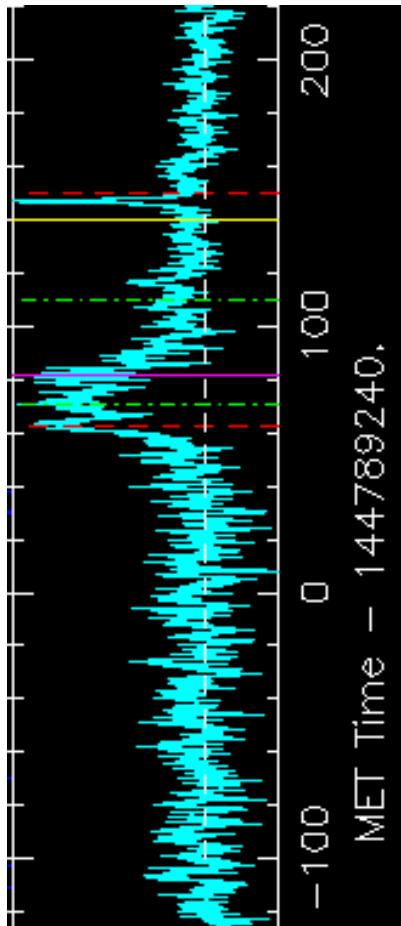
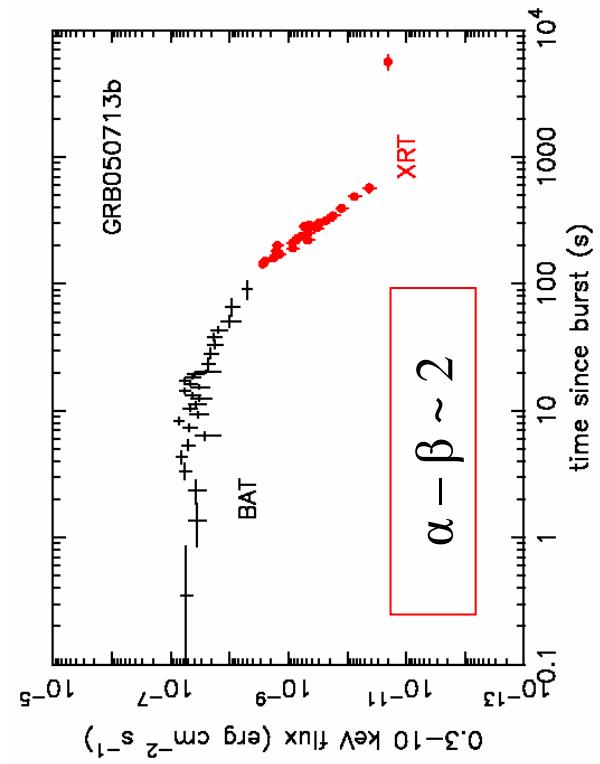
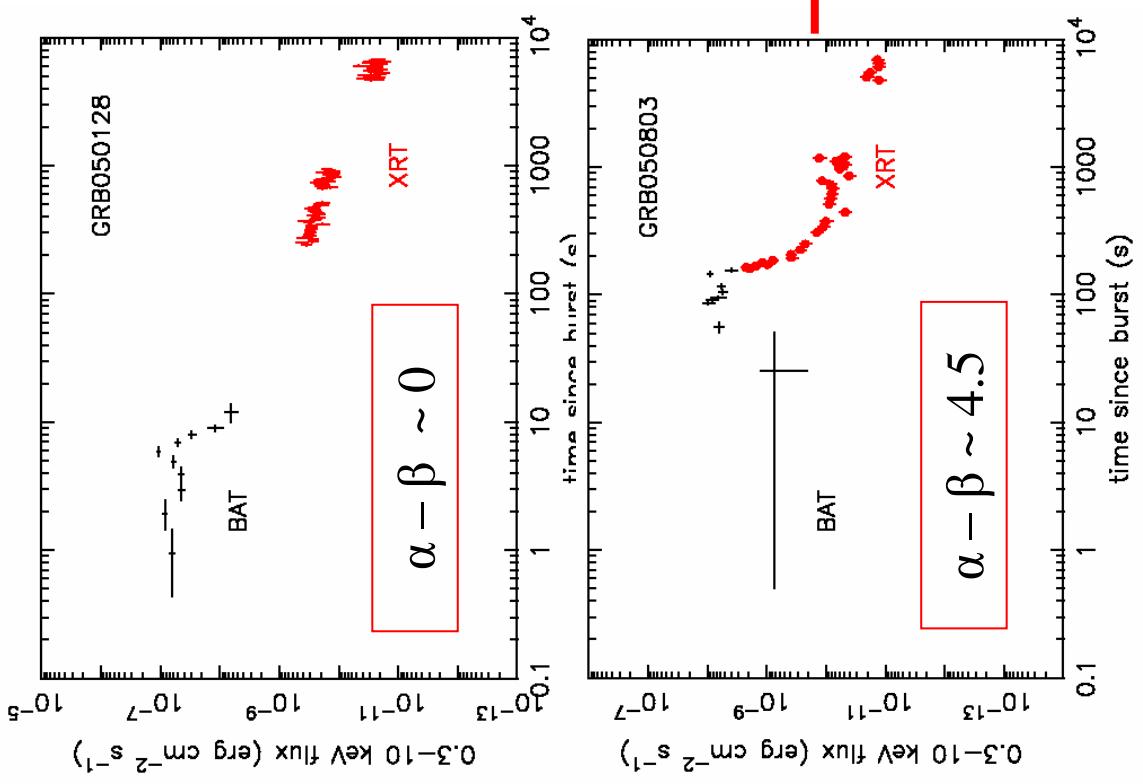




Temporal & spectral (using BAT trigger time at zero)



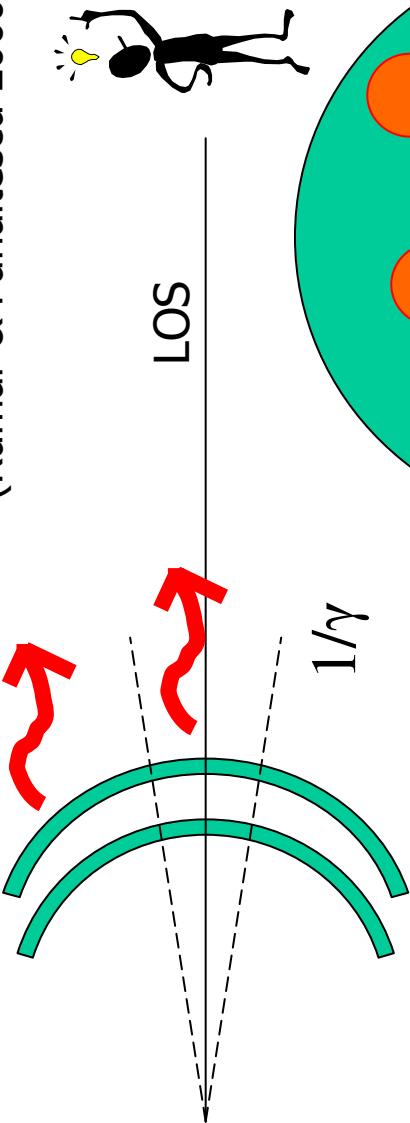
Examples from each “group”



Some rapid decay models

(1) High Latitude emission

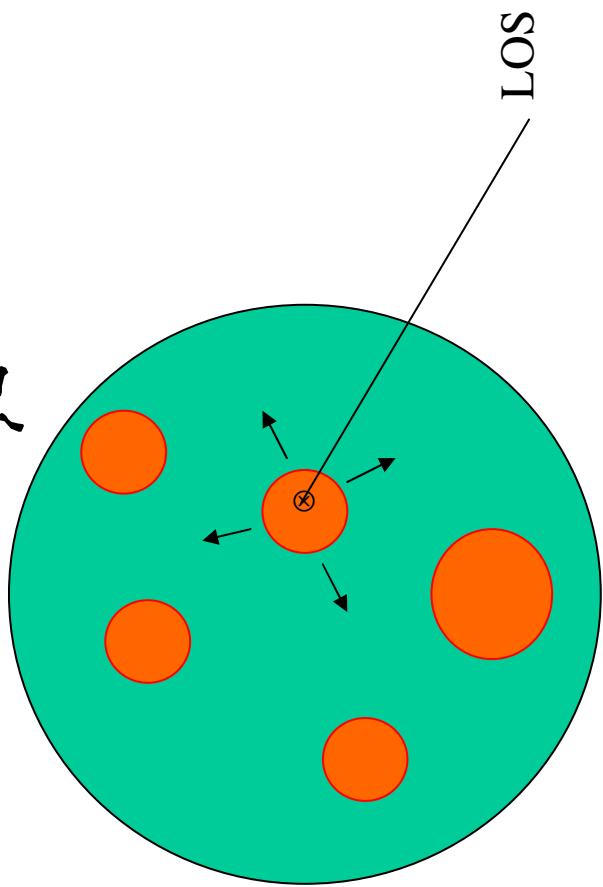
After internal shocks terminate, photons from high latitude dominates
(Kumar & Panaitecu 2000; S.K, Piran & Sari 1997)



expect $\alpha - \beta \approx 2$

(2) Patchy shell

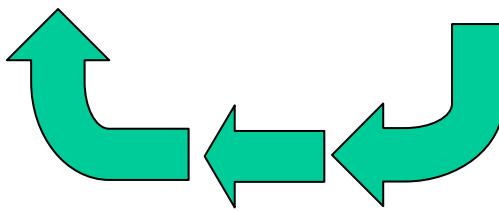
After internal shocks terminate from “bright spot”, see rapid decline in photons – but expect a “bumpy” light curve?





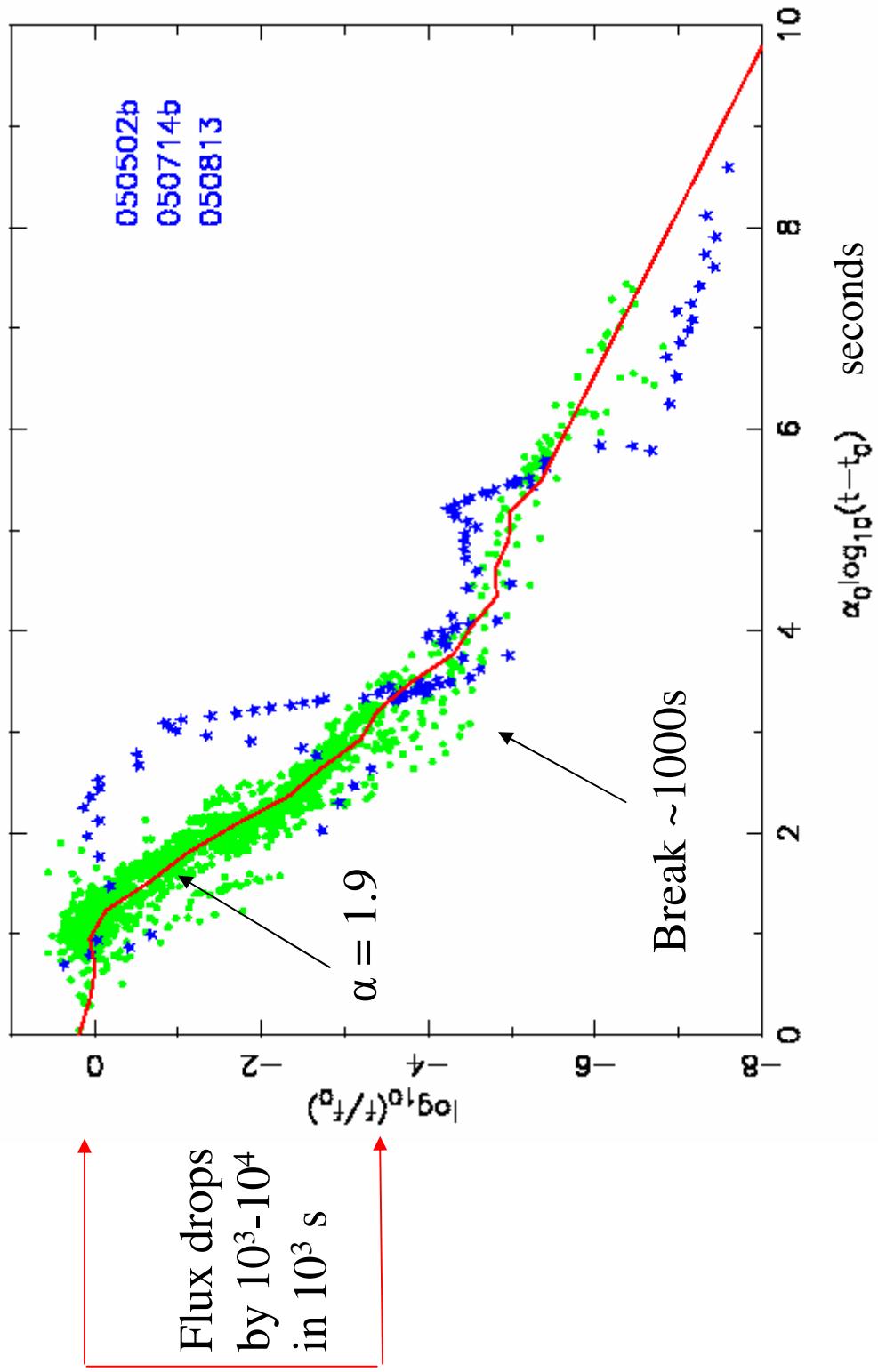
Making a mean GRB

- Normalise flux over T_{90} to mean flux over T_{90}
- Construct mean light curve
- Determine “stretch/squeeze” factor and shift to minimise dispersion of each GRB relative to the mean
- Re-compute mean light curve
- Iterate until convergence
- Can then compute “scaled” decay rates. Also need to consider what spectral index to compare with.



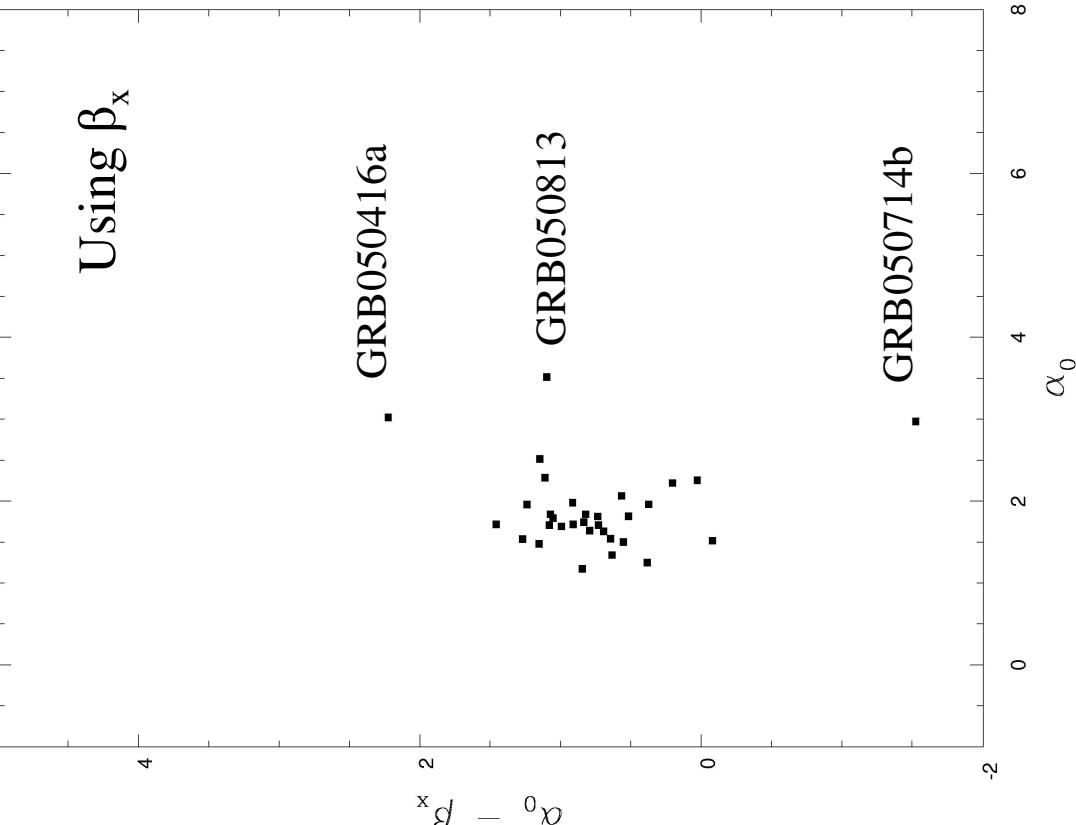
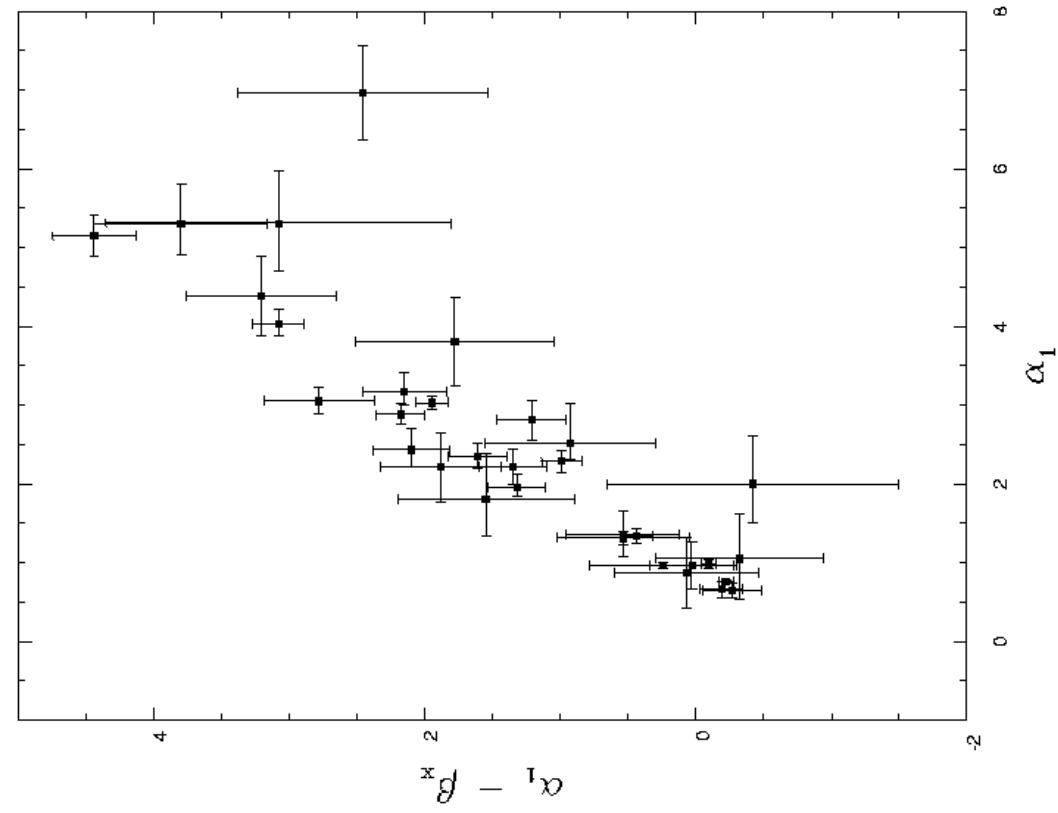


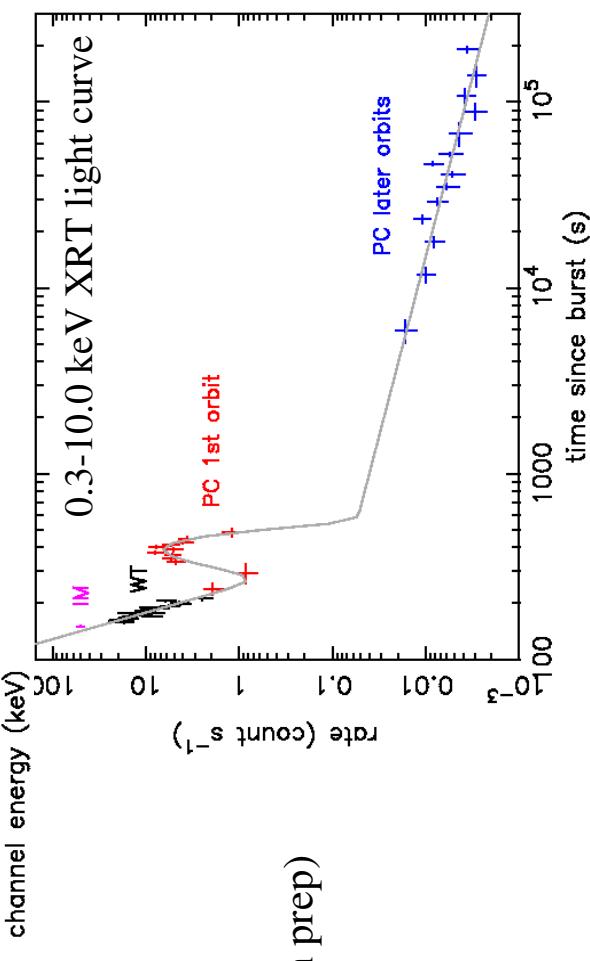
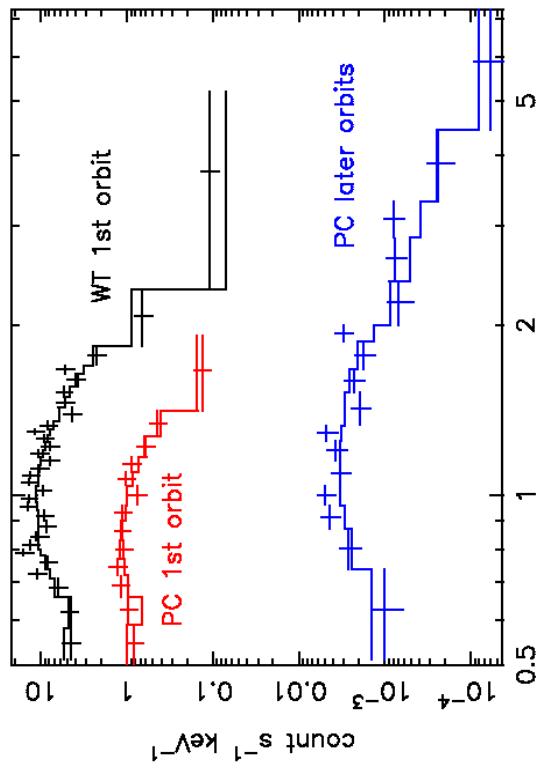
Mean GRB light curve



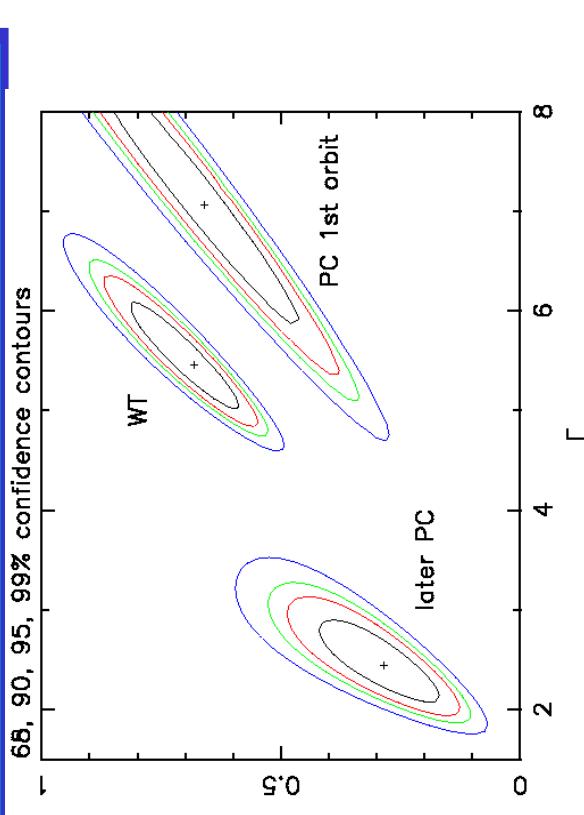


Observed (α_1) cf. scaled (α_0)

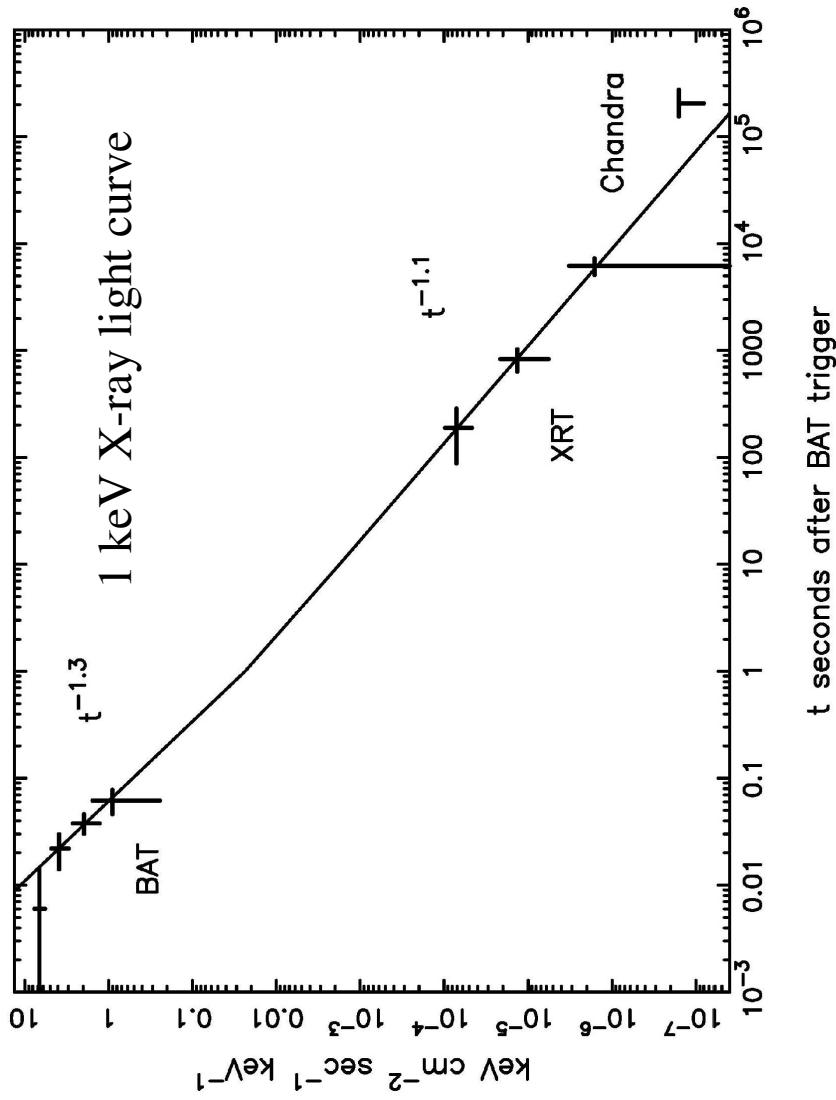




(Levan et al. in prep)



pre-break decay slope:
 $6.98 +/- 0.62$
break time:
 $365 +/- 35$ s
post-break decay slope:
 $0.52 +/- 0.11$



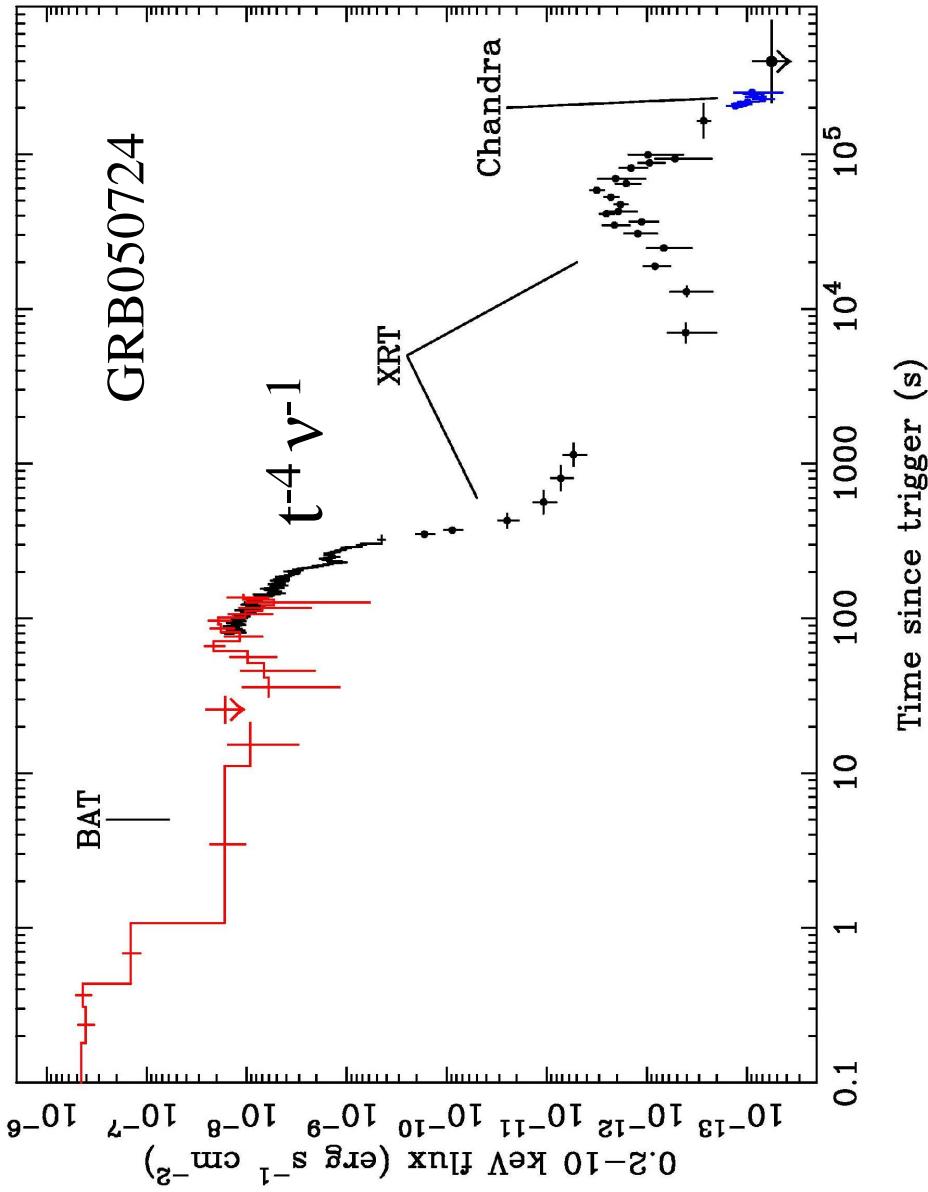
BAT+XRT emission consistent with a single decay rate of 1.2 ± 0.09

(Gehrels et al. 2005, Nature, in press)



What about short bursts?

GRB050724 looks long to BAT ($T_{90}=153\text{s}$), but would be short to BATSE ($<1\text{s}$)

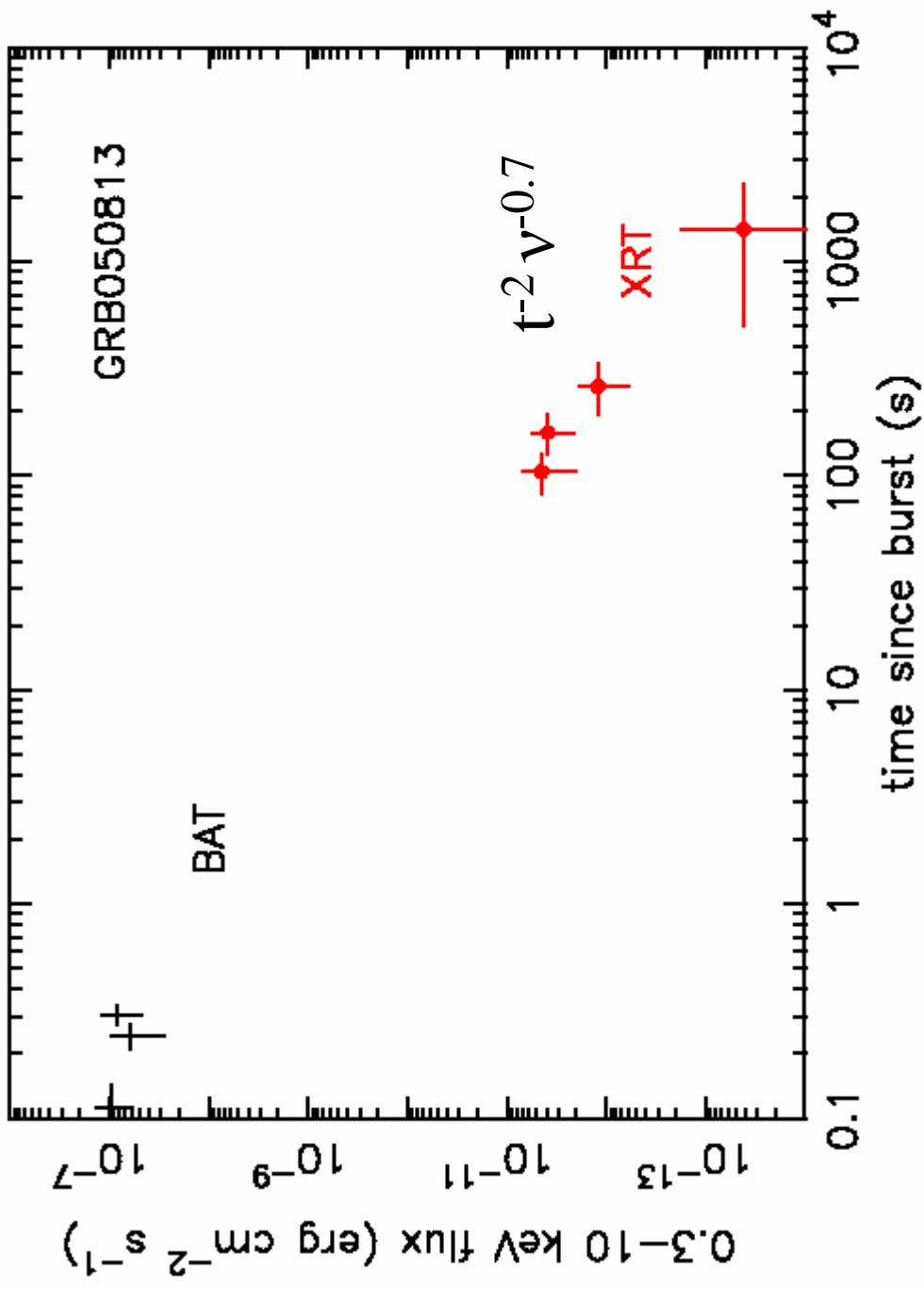




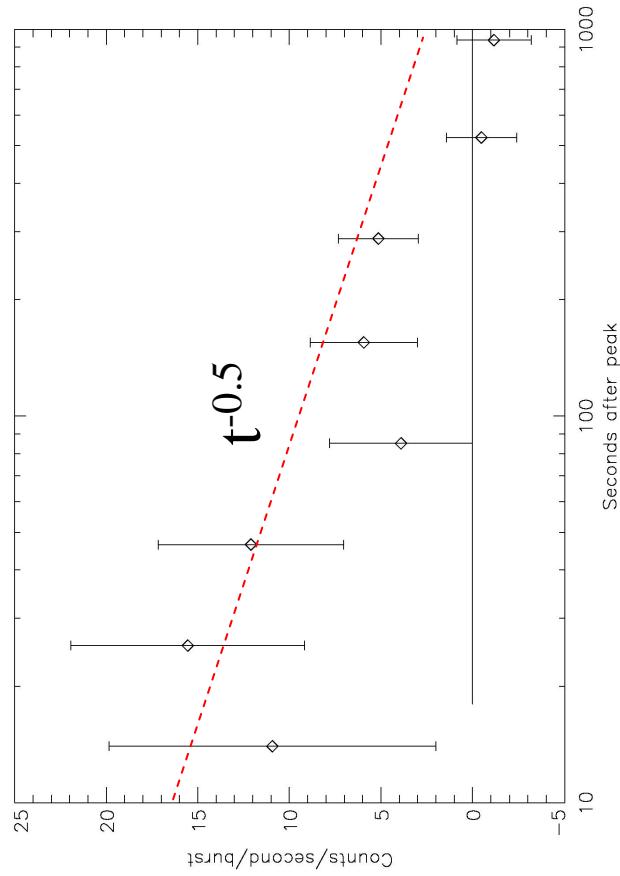
GRB050813 ($T_{90}=0.58$ s)



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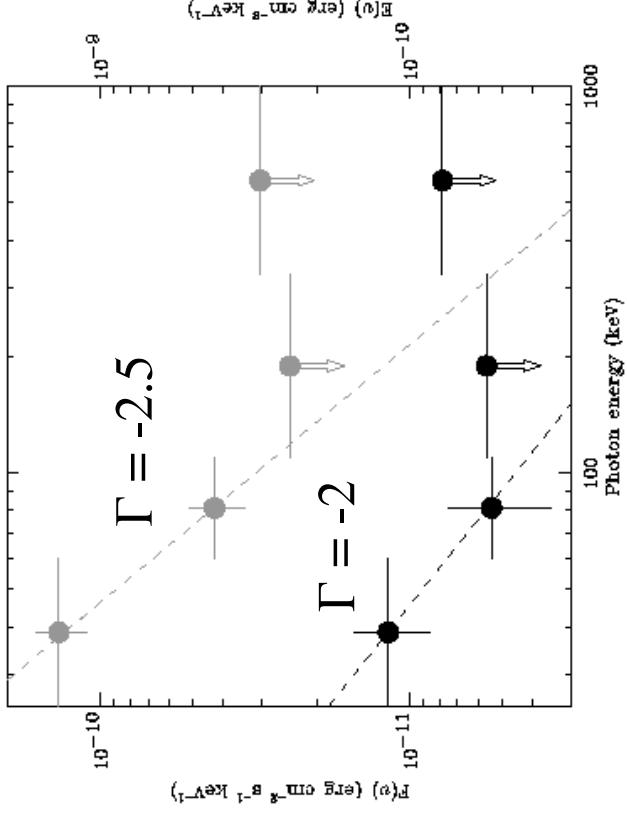
BATSE short GRBs



Connaughton (2002) - summed light
curve for 100 short bursts ($t_{90} < 2$ s).

Lazzati et al. (2002) - spectrum for 76
short bursts (black is the spectrum at 30s;
grey is the time integrated spectrum).

Count rate ~0.1 that of long bursts.



Summary

- The early XRT light curves seem to be associated with the prompt emission seen in the BAT
- The X-ray initial steep decline breaks at a time of around 1000s) to something shallower with a similar spectral index
- High latitude emission may explain the relative temporal and spectral indices and the rapid decline rate-of-decay
- Later, post-break, emission may correspond to re-energised emission and/or standard afterglow (Zhang et al. 2005; Nousek et al. 2005)
- At least some short bursts seem to behave in a similar way to long bursts – the engine may be alive for longer than thought?



The End